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Publication number:

0 360 540  
A2



## EUROPEAN PATENT APPLICATION

(2) Application number: 89309471.4

(5) Int. Cl. 5. H03K 19/177

(22) Date of filing: 19.09.89

(30) Priority: 20.09.88 JP 235293/88

(43) Date of publication of application:  
28.03.90 Bulletin 90/13

(44) Designated Contracting States:  
DE FR GB NL

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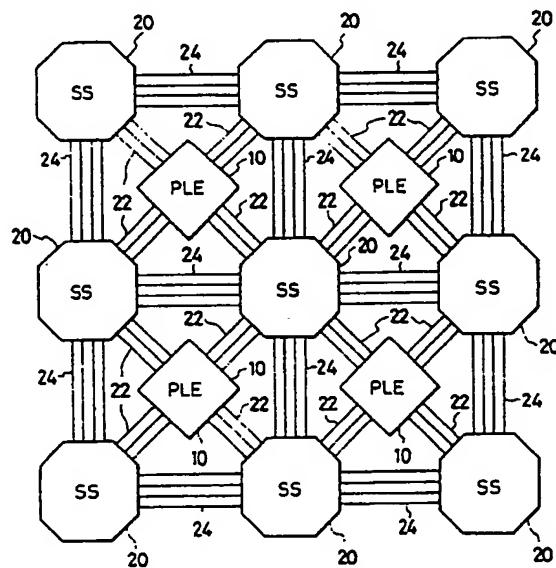
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(54) Programmable logic device.

(57) There is provided a programmable logic device (PLD) which includes a programmable wiring, the programmable wiring comprising: a plurality of switch stations (SS), first wirings (22) each for directly connecting some terminals among input/output terminals of said SSs to input/output terminals of adjacent programmable logic elements (PLE), and second wirings (24) each for directly connecting some terminals among the input/output terminals of said SSs to input/output terminals of the adjacent SS. Hereby, the numbers of involved switches, through which associated signals pass, can be reduced.

FIG. 1



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### Programmable logic device

The present invention relates to a programmable logic device which permits a user to electrically program an arbitrary logic circuit at his hand, and more specifically to an improved programmable logic device, which includes a highly functional programmable wiring of a reduced occupation area that comprises a plurality of programmable logic elements, the programmable logic elements being connected with each other through the programmable wiring.

There is conventionally known a programmable logic device (hereinafter simply referred to as a PLD), that is an integrated circuit with which a user can construct an arbitrary logic circuit at his hand.

The prior PLD primarily includes a programmable logic element (hereinafter simply referred to as a PLE) which is configurable to construct a user's own logic, a circuit function-defining memory cell for defining the logic function of the PLE and an interconnection relation among internal wirings, an programmable input/output block (hereinafter simply referred to as an IOB) for interfacing between external device packaging pins and an internal logic circuit (i.e. the PLE), and a programmable wiring for establishing a wiring path to connect input/output signals into/from the IOB and the PLE to a desired network.

The programmable wiring is hitherto comprised, as illustrated for example in Fig. 9, of horizontal wirings 12 disposed between adjacent lines of the respective PLEs 10 (and IOBs) vertical wirings 14 disposed between adjacent columns of the respective PLEs 10 (and IOBs), switching matrixes 16 including interwiring switches 16A each disposed at intersections of the lines and the columns of the respective horizontal and vertical wirings 12 and 14 for interconnecting the wirings from the adjacent columns and lines, and input/output switches (hereinafter referred to as IOSs) 18 each disposed at position correspondingly to the adjacent PLEs 10 of the respective wirings 12 and 14 for connecting inputs and outputs into and from the adjacent PLEs 10 to the wirings 12 or 14.

The interwiring switches 16A and IOS 18 are controllable by each bit of circuit function-defining data, respectively, for establishing arbitrary wiring.

However, since in such a prior PLD, the IOSs 18 of the respective PLEs 10 and the interwiring switches 16A are independently provided, interconnection between the two PLEs 10 requires two, without fail, IOSs 18 and at least one switching matrix 16 although they are disposed far away or just adjacently, further requiring an increased number of the switches and complicated wiring, followed by a large occupation area of the PLD.

Additionally, there are required many gates or switches, through which associated signals pass, thereby attenuating the signals and lowering the reliability of the device.

5 In view of the drawbacks of the prior art, it is an object of the present invention to provide a PLD capable of optimizing a programmable wiring and of achieving the high function and reduced occupation area thereof.

10 In accordance with the present invention, there is provided a PLD including a plurality of programmable logic elements connected to each other through a programmable wiring, said programmable wiring comprising a plurality of switch stations each having a plurality of input/output terminals and each including therein switch elements for interconnecting said input/output terminals, first wirings each for directly connecting some terminals among said input/output terminals of said switch stations to input/output terminals of said adjacent logic elements, and second wirings each for directly connecting some terminals among said input/output terminals of said switch stations to the input/output terminals of the adjacent switch stations.

15 The present inventors have found in their investigation of many design examples that most part (over 60 %) of wirings among the PLEs interconnects the adjacent PLEs.

20 The present invention, which is based upon such investigations, facilitates interconnection between the adjacent PLEs to achieve its high function and its reduced occupation area.

25 In a primary aspect of the present invention, as illustrated in Fig. 1, the aforementioned programmable wiring comprises a plurality of switch stations (hereinafter simply referred to as SSs) 20, first wiring 22 located diagonally in the figure each for directly connecting some terminals among the input/output terminals of the SSs 20 to the adjacent PLEs 10, and second wirings 24 located vertically and horizontally in the figure for directly connecting some terminals among the input/output terminals of the SSs 20 to the adjacent SSs. Here, the PLE 10 may include the input/output terminals: A, Din, B, C, RD, W, Y, K, D, Z, CE and X, as illustrated in Fig. 2 for example. Likewise, the SS 20 may include the input/output terminals: Y, K, D, W1 - W4, Z, CE, X, S1 - S4, A, Din, B, E1 - E4, W, RD, C and N1 - N4, as illustrated in Fig. 3 for example.

30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 435 440 445 450 455 460 465 470 475 480 485 490 495 500 505 510 515 520 525 530 535 540 545 550 555 560 565 570 575 580 585 590 595 600 605 610 615 620 625 630 635 640 645 650 655 660 665 670 675 680 685 690 695 700 705 710 715 720 725 730 735 740 745 750 755 760 765 770 775 780 785 790 795 800 805 810 815 820 825 830 835 840 845 850 855 860 865 870 875 880 885 890 895 900 905 910 915 920 925 930 935 940 945 950 955 960 965 970 975 980 985 990 995 1000 1005 1010 1015 1020 1025 1030 1035 1040 1045 1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100 1105 1110 1115 1120 1125 1130 1135 1140 1145 1150 1155 1160 1165 1170 1175 1180 1185 1190 1195 1200 1205 1210 1215 1220 1225 1230 1235 1240 1245 1250 1255 1260 1265 1270 1275 1280 1285 1290 1295 1300 1305 1310 1315 1320 1325 1330 1335 1340 1345 1350 1355 1360 1365 1370 1375 1380 1385 1390 1395 1400 1405 1410 1415 1420 1425 1430 1435 1440 1445 1450 1455 1460 1465 1470 1475 1480 1485 1490 1495 1500 1505 1510 1515 1520 1525 1530 1535 1540 1545 1550 1555 1560 1565 1570 1575 1580 1585 1590 1595 1600 1605 1610 1615 1620 1625 1630 1635 1640 1645 1650 1655 1660 1665 1670 1675 1680 1685 1690 1695 1700 1705 1710 1715 1720 1725 1730 1735 1740 1745 1750 1755 1760 1765 1770 1775 1780 1785 1790 1795 1800 1805 1810 1815 1820 1825 1830 1835 1840 1845 1850 1855 1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020 2025 2030 2035 2040 2045 2050 2055 2060 2065 2070 2075 2080 2085 2090 2095 2100 2105 2110 2115 2120 2125 2130 2135 2140 2145 2150 2155 2160 2165 2170 2175 2180 2185 2190 2195 2200 2205 2210 2215 2220 2225 2230 2235 2240 2245 2250 2255 2260 2265 2270 2275 2280 2285 2290 2295 2300 2305 2310 2315 2320 2325 2330 2335 2340 2345 2350 2355 2360 2365 2370 2375 2380 2385 2390 2395 2400 2405 2410 2415 2420 2425 2430 2435 2440 2445 2450 2455 2460 2465 2470 2475 2480 2485 2490 2495 2500 2505 2510 2515 2520 2525 2530 2535 2540 2545 2550 2555 2560 2565 2570 2575 2580 2585 2590 2595 2600 2605 2610 2615 2620 2625 2630 2635 2640 2645 2650 2655 2660 2665 2670 2675 2680 2685 2690 2695 2700 2705 2710 2715 2720 2725 2730 2735 2740 2745 2750 2755 2760 2765 2770 2775 2780 2785 2790 2795 2800 2805 2810 2815 2820 2825 2830 2835 2840 2845 2850 2855 2860 2865 2870 2875 2880 2885 2890 2895 2900 2905 2910 2915 2920 2925 2930 2935 2940 2945 2950 2955 2960 2965 2970 2975 2980 2985 2990 2995 3000 3005 3010 3015 3020 3025 3030 3035 3040 3045 3050 3055 3060 3065 3070 3075 3080 3085 3090 3095 3100 3105 3110 3115 3120 3125 3130 3135 3140 3145 3150 3155 3160 3165 3170 3175 3180 3185 3190 3195 3200 3205 3210 3215 3220 3225 3230 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7235 7240 7245 7250 7255 7260 7265 7270 7275 7280 7285 7290 7295 7300 7305 7310 7315 7320 7325 7330 7335 7340 7345 7350 7355 7360 7365 7370 7375 7380 7385 7390 7395 7400 7405 7410 7415 7420 7425 7430 7435 7440 7445 7450 7455 7460 7465 7470 7475 7480 7485 7490 7495 7500 7505 7510 7515 7520 7525 7530 7535 7540 7545 7550 7555 7560 7565 7570 7575 7580 7585 7590 7595 7600 7605 7610 7615 7620 7625 7630 7635 7640 7645 7650 7655 7660 7665 7670 7675 7680 7685 7690 7695 7700 7705 7710 7715 7720 7725 7730 7735 7740 7745 7750 7755 7760 7765 7770 7775 7780 7785 7790 7795 7800 7805 7810 7815 7820 7825 7830 7835 7840 7845 7850 7855 7860 7865 7870 7875 7880 7885 7890 7895 7900 7905 7910 7915 7920 7925 7930 7935 7940 7945 7950 7955 7960 7965 7970 7975 7980 7985 7990 7995 8000 8005 8010 8015 8020 8025 8030 8035 8040 8045 8050 8055 8060 8065 8070 8075 8080 8085 8090 8095 8100 8105 8110 8115 8120 8125 8130 8135 8140 8145 8150 8155 8160 8165 8170 8175 8180 8185 8190 8195 8200 8205 8210 8215 8220 8225 8230 8235 8240 8245 8250 8255 8260 8265 8270 8275 8280 8285 8290 8295 8300 8305 8310 8315 8320 8325 8330 8335 8340 8345 8350 8355 8360 8365 8370 8375 8380 8385 8390 8395 8400 8405 8410 8415 8420 8425 8430 8435 8440 8445 8450 8455 8460 8465 8470 8475 8480 8485 8490 8495 8500 8505 8510 8515 8520 8525 8530 8535 8540 8545 8550 8555 8560 8565 8570 8575 8580 8585 8590 8595 8600 8605 8610 8615 8620 8625 8630 8635 8640 8645 8650 8655 8660 8665 8670 8675 8680 8685 8690 8695 8700 8705 8710 8715 8720 8725 8730 8735 8740 8745 8750 8755 8760 8765 8770 8775 8780 8785 8790 8795 8800 8805 8810 8815 8820 8825 8830 8835 8840 8845 8850 8855 8860 8865 8870 8875 8880 8885 8890 8895 8900 8905 8910 8915 8920 8925 8930 8935 8940 8945 8950 8955 8960 8965 8970 8975 8980 8985 8990 8995 9000 9005 9010 9015 9020 9025 9030 9035 9040 9045 9050 9055 9060 9065 9070 9075 9080 9085 9090 9095 9100 9105 9110 9115 9120 9125 9130 9135 9140 9145 9150 9155 9160 9165 9170 9175 9180 9185 9190 9195 9200 9205 9210 9215 9220 9225 9230 9235 9240 9245 9250 9255 9260 9265 9270 9275 9280 9285 9290 9295 9300 9305 9310 9315 9320 9325 9330 9335 9340 9345 9350 9355 9360 9365 9370 9375 9380 9385 9390 9395 9400 9405 9410 9415 9420 9425 9430 9435 9440 9445 9450 9455 9460 9465 9470 9475 9480 9485 9490 9495 9500 9505 9510 9515 9520 9525 9530 9535 9540 9545 9550 9555 9560 9565 9570 9575 9580 9585 9590 9595 9600 9605 9610 9615 9620 9625 9630 9635 9640 9645 9650 9655 9660 9665 9670 9675 9680 9685 9690 9695 9700 9705 9710 9715 9720 9725 9730 9735 9740 9745 9750 9755 9760 9765 9770 9775 9780 9785 9790 9795 9800 9805 9810 9815 9820 9825 9830 9835 9840 9845 9850 9855 9860 9865 9870 9875 9880 9885 9890 9895 9900 9905 9910 9915 9920 9925 9930 9935 9940 9945 9950 9955 9960 9965 9970

one SS 20.

Additionally, since the direction of a wiring, through which an associated signal is transmitted, connected to the SS 20 can be clarified to make clear a relationship between the input and output of the SS 20, there is no need of unnecessarily switching among the outputs of the SS 20, differing from the prior case. Thus, any wiring path, which is not in need of connection, can be made obvious, thereby optimizing the circuit to, in this respect, reduce the number of the switches.

Furthermore, if there are any equivalent PLE input/outputs, then they can be taken into consideration clearly, so that flexibility of the wiring is less reduced even when a circuit construction is adopted with a reduced number of the switches and with many restrictions.

In accordance with the present invention, as described above, there is no need of providing such an IOS as in the prior case and hence the number of the switches can be reduced, thereby allowing any wiring to be reduced, resulting in a high function. In particular, wiring between the adjacent PLEs can be overwhelmingly advantageous. In addition, the reduction of the number of the switches can realize the reduced occupation area of the device.

More specifically, if the direction of wiring would be changed between the first and second wirings, it might facilitate the discrimination therebetween.

The exact nature of this invention, as well as other objects and advantages thereof, will be readily apparent from consideration of the following specification relating to the accompanying drawings, in which like reference characters designate the same or similar parts throughout the figures thereof and wherein:

Fig. 1 is a block diagram illustrating the basic arrangement of a programmable logic device (PLD) according to the present invention;

Fig. 2 is a block diagram exemplarily illustrating input/output terminals of a programmable logic element (PLE) for use in the PLD of Fig. 1;

Fig. 3 is a block diagram exemplarily illustrating input/output terminals of a switch station (SS) for use in the PLD of Fig. 1;

Fig. 4 is a block diagram illustrating the function of the PLD according to the present invention;

Fig. 5 is a block diagram illustrating the construction of an embodiment of the PLD according to the present invention;

Fig. 6 is a block diagram illustrating the construction of a PLE for use in the embodiment;

Fig. 7 is a block diagram exemplarily illustrating a switch table of a switch station for use in the embodiment of Fig. 5;

Fig. 8 is a circuit diagram exemplarily illustrating a circuit of the switch station constructed on the basis of the switch tabl of Fig. 7; and

Fig. 9 is a block diagram exemplarily illustrating a prior PLD including a prior programmable wiring.

In what follows, a preferred embodiment according to the present invention will be described in detail with refernce to the accompanying drawings.

As shown in Fig. 5, the embodiment provide a PLD which includes a plurality of PLEs 10 connected to each other through a programmable wiring. The programmable wiring comprises a plurality of SSs 20, each of which has a plurality of input/output terminals, X, W, Q, S1, S2, B, A, E, CK, C, N1 and N2 and includes a switch 20A as shown in Fig. 8, for interconnecting the input/output terminals to each other, first wirings 22 located diagonally in the figure for directly connecting some terminals X, Q, B, A, CK and C of the input/output terminals of the SS 20 to the adjacent PLEs 10, and second wirings 24 located horizontally and vertically in the figure for directly connecting remaining terminals W, S1, S2, E, N1 and N2 of the input/output terminals of the SS 20 to the adjacent SSs 20.

The PLE 10 may be a sequential circuit, which includes, as illustrated in Fig. 6, a combined logic circuit (e.g., an AND circuit) 10A, into which general purpose inputs A, B and C are inputted, and a flip-flop 10B for delaying a combined logic output X from the combined logic circuit 10A in response to a clock CK to generate an output Q.

The SS 20 may be one to realize a switch table such for example as that illustrated in Fig. 7. The SS 20 which realize such a switch table of Fig. 7, may be constructed, as illustrated in Fig. 8 for example, with many switch elements 20A.

In the present embodiment, an arbitrary sequential circuit can be assured by programming in proper a function in each PLE 10, which is a sequential circuit, as well as wiring in the SS 20.

In accordance with the present embodiment, the first wirings 22 have same directions (diagonal directions) of wiring and the second wirings 24 have same directions (up-down and right-left directions) of wiring different from the first wirings 22, thereby facilitating the discrimination of any wiring among the wirings.

Although in the above embodiment the PLE 10 was the sequential circuit including the combined logic circuit 10A and the flip-flop 10B, the PLE 10 may be constructed without limitation thereto.

Additionally, the switch table, which can be realized by the SS 20, and the practice thereof are also not limited to the present embodiment.

Although a certain preferred embodiment has

been shown and described, it should be understood that many changes and modifications may be made therein without departing from the scope of the appended claims.

5

### Claims

1. A programmable logic device including a plurality of programmable logic elements (10) connected to each other through a programmable wiring, said programmable wiring comprising:  
plurality of switch stations (20) each having a plurality of input/output terminals, each switch station including therein switch elements (20A) each for interconnecting said input/output terminals;  
first wirings (22) each for directly connecting some terminals among said input/output terminals of said switch stations (20) to input/output terminals of the adjacent logic elements (10); and  
second wirings (24) each for directly connecting some terminals among said input/output terminals of said switch stations (20) to the input/output terminals of the adjacent switch stations.  
2. A programmable logic device according to claim 1 wherein said first wirings (22) have same directions of wiring and said second wirings (24) have same directions of wiring different from said first wiring.  
3. A programmable logic device according to claim 1 wherein said switch station (20) comprises many switch elements (20A) to realize a predetermined switch table.  
4. A programmable logic device according to claim 1 wherein said programmable logic element (10) is a sequential circuit which comprises a combined logic circuit (10A), into which any general-purpose input is inputted, and a flip-flop (10B) for delaying a combined logical output from said combined logic circuit in response to a clock signal (CK) to generate a delayed output (Q).

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FIG. 1

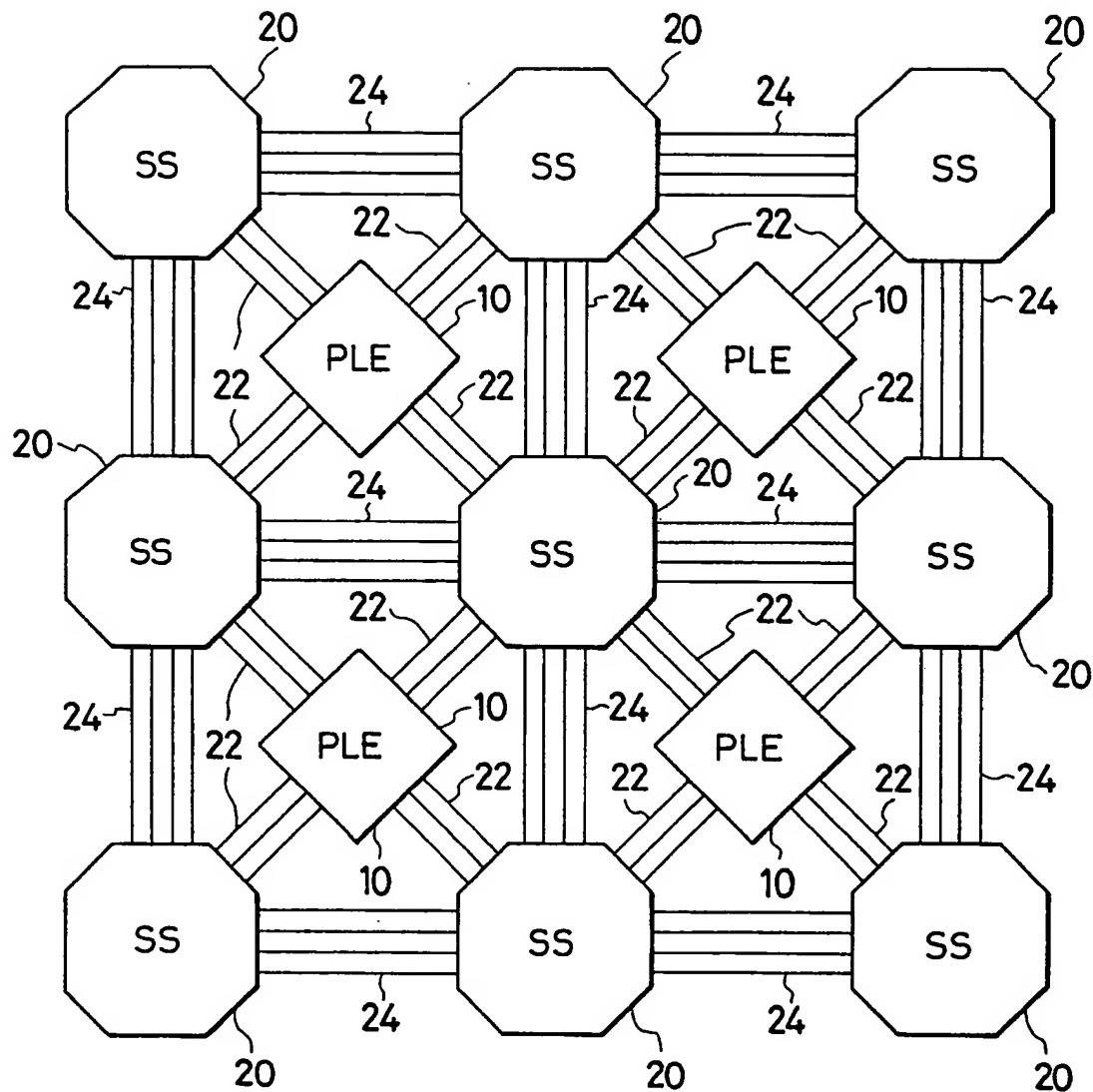


FIG.2

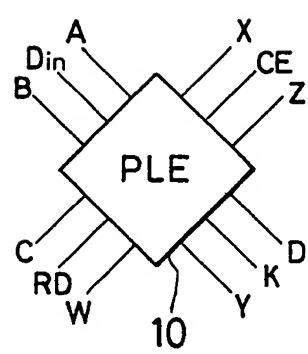


FIG.3

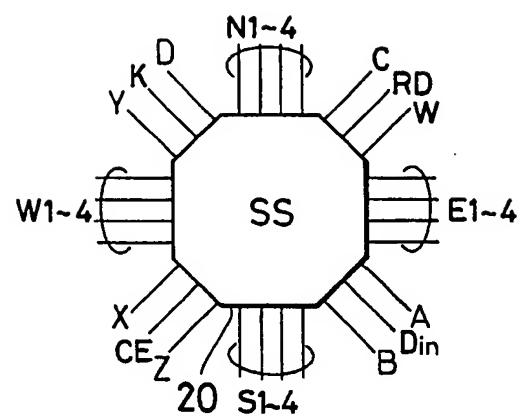


FIG.4

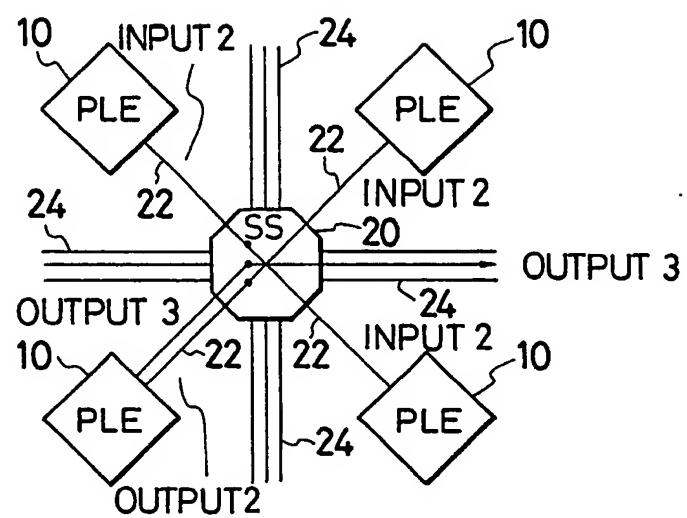


FIG.5

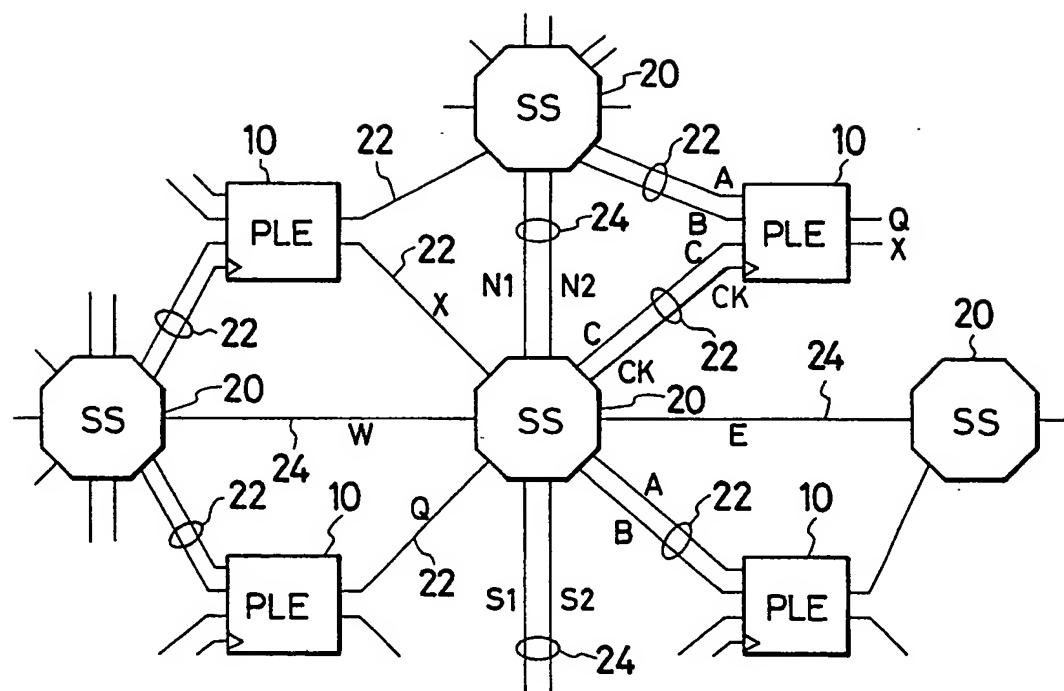


FIG.6

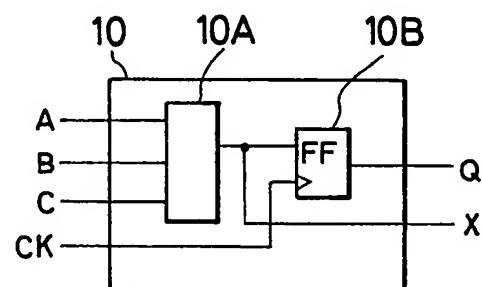


FIG.7

	A	B	C	CK	X	Q	N1	N2	S1	S2	W	E
A					1		1		1		1	
B						1			1		1	
C						1	1		1	1	1	
CK					1					1	1	
X	1	1	1				1		1	1	1	
Q		1	1					1	1	1	1	1
N1	1					1			1	1		
N2			1				1			1	1	
S1	1					1	1				1	
S2		1	1				1	1				1
W	1	1	1	1	1	1	1		1			1
E	1	1	1	1	1	1	1		1	1		1

1---WITH SWITCH

FIG.8

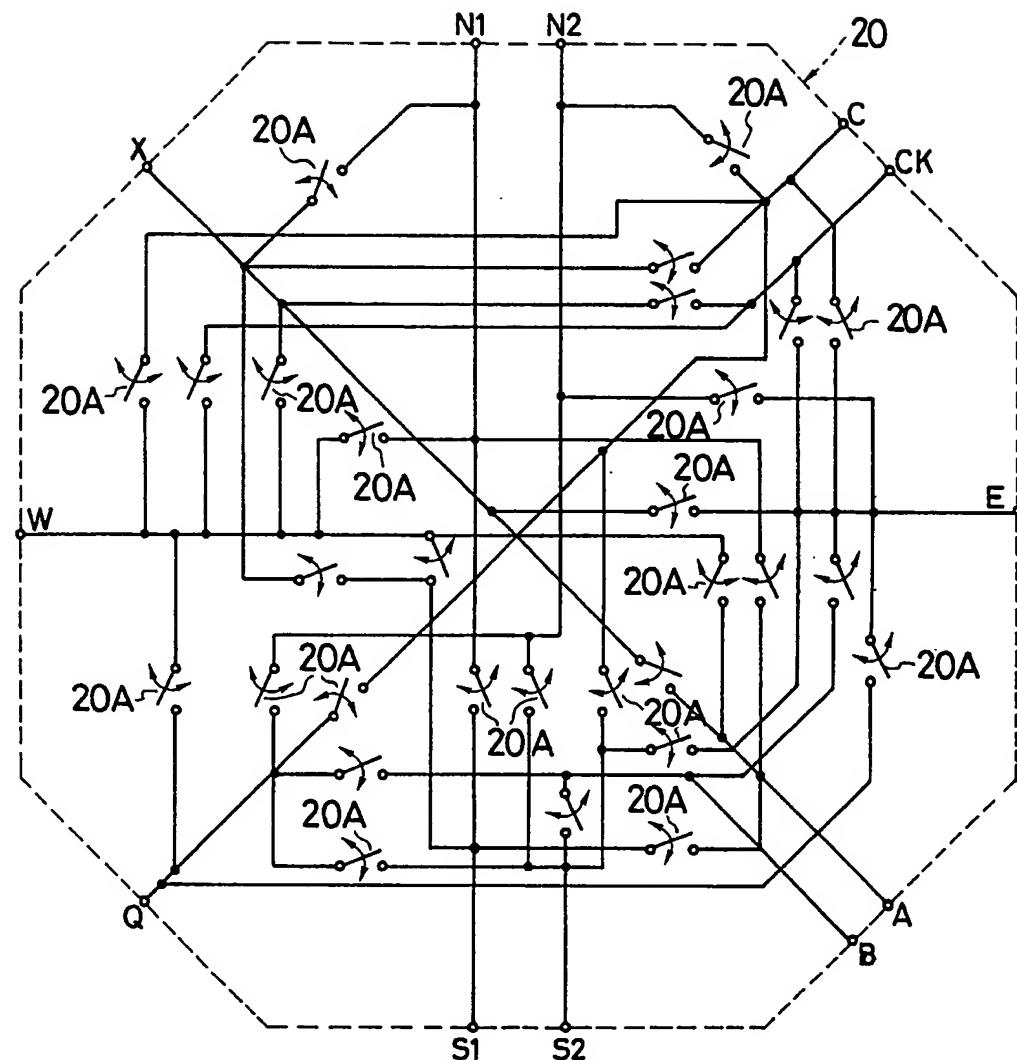


FIG.9

